Discussion

Dr Christopher A. Caldarone *(Toronto, Ontario, Canada).* Dr Kitahori, that was a very nice presentation.

Dr Kitahori has described a series of high-risk hypoplastic left heart syndrome (HLHS) patients treated with bilateral pulmonary artery (PA) banding (bPAB). He has tried to clarify the relationship between the geometry of the PA band and arterial oxygen saturation (SaO_2) at the second-stage procedure.

In a fully grown neonate, this might not be as important because numerous clinical reports have described the use of 3.5-mm diameter polytetrafluoroethylene shunts wrapped around the branch PAs. We have used this technique at the Hospital for Sick Children, and it seems to work well. We have typically evaluated the banding at the end of the procedure with angiography, but our approach has been very subjective. Dr Kitahori is to be applauded for trying to create some objective criteria for how to define these bands.

This is even more important in the small neonates in whom the degree of banding is very difficult to adjust precisely. Small changes in the circumference of a band will result in large changes in the internal diameter and, consequently, even greater changes in the resistance across the band.

We have competing interests in these small infants in that we want the bands tight enough to restrict pulmonary blood flow, prevent volume overload, and maintain adequate diastolic pressures, and, at the same time, we want the bands loose enough to allow adequate SaO_2 at banding and adequate SaO_2 to be able to persist to the time of the second-stage procedure, a difficult balancing act in these very small infants. For that reason, this is an important contribution because you are trying to define the relationship between the geometry at banding and the subsequent SaO_2.

As we discussed, I think the model would benefit if you could create a model that was derived solely from variables determined at bPAB. However, putting that aside, it would be a very valuable addition and perhaps something you could study in the future.

With regard to questions regarding the presented data, I have 3.

First, could you describe what clinical parameters are used when the bands were constructed in your series. Each band really must be assessed individually. Simply using the systemic SaO_2 would be inappropriate, because, as you know, you could have complete occlusion of 1 pulmonary artery and a very loose band on the other and have seemingly appropriate systemic SaO_2. Thus, each band really should be evaluated independently. How do you interrogate the bands and determine the appropriate tightness of the bands?

Dr Kitahori. Thank you, Dr Caldarone.

The infants' body weight varies so much, from 1.5 to 4 kg. This is a very large difference. We thought the PA band should be adjusted to the suitable size, because the PA band on the main PA trunk is adjusted according to Trusler's rule. Mainly, we have monitored the SaO_2 in the operating room. In addition, we usually use transesophageal echocardiography (TEE). TEE is also useful. Using TEE, we can see the pulmonary venous (PV) return well, and we can check the balance of the right and left PV return. Also, the bilateral PV return should be equivalent after bPAB. If the PV return of 1 side exceeds the other too much, the PA band should be readjusted to be tighter or the other looser. However, we do not yet have any clear criteria for the evaluation using TEE, such as the exact value of the flow velocity of the PA band. We just see the balance. Although our TEE probe is the smallest available, it is sometimes difficult to measure the blood flow velocity in the PA precisely, because the echoprobe direction does not always fit the blood flow direction. In such cases, we could over- or underestimate the flow velocity. Thus, evaluation using TEE is a future work for us—how to use TEE for the measurement of a precise evaluation of the PA band.

Dr Caldarone. All right. Well, assuming that you have perfectly symmetric pulmonary artery bands, what is the appropriate SaO_2 at PA banding?

Dr Kitahori. We adjust the PA band with help of TEE. Our goal for SaO_2 is about 80% and 85% at maximum. In my opinion, the SaO_2 in the operating room should be in the slightly lower range, meaning 80%, because the SaO_2 usually gradually increases a little bit after surgery. As you said, we want to reduce the volume overload as much as possible, but we have to keep the SaO_2 at a good level. Thus, the SaO_2 must not be going to be quite low, which would result in a lethal level. Thus, I think 80% would be good.

Dr Caldarone. My third question. In the manuscript you reported that you administer prostaglandin to the infants from bPAB to the second-stage procedure and thus you do not require ductal stenting. This would eliminate the potential for duct-induced stenosis of the aortic isthmus and thereby a problem with retrograde flow in the aortic arch.

Two questions regarding that. First, did you have any complications associated with prolonged prostaglandin infusion? Second, at the second-stage procedure, did you see any stenosis or other anatomic abnormality in the isthmus?

Dr Kitahori. The reported side effects of prostaglandin have been apnea and thickening of the periosteum of the long bone. One patient had an apnea attack, but it was not so severe, and reintubation was not needed. We have never observed thickening of the periosteum of the long bone to date. In our institute, prostaglandin E_1 administration is considered very safe and useful for maintaining the patent ductus arteriosus (PDA). The only problem has been the long hospital stay. Patients receiving prostaglandin cannot go home. At that point, a PDA stent might be superior. However, it has some problems, as you mentioned. The PDA stent can migrate and interfere with the blood flow of the transverse arch. It is dangerous because the blood supply to coronary artery is also interfered. In my opinion, the frequency of complications related to prostaglandin might be smaller than that of the PDA stent, so we chose prostaglandin.

Dr James S. Tweddell *(Milwaukee, Wis).* Can I just ask 1 follow-up question to Dr Caldarone. What is the fraction of inspiratory oxygen when you are doing the banding?

Dr Kitahori. Usually the fraction of inspiratory oxygen is set at 21%.

Dr Tweddell. 21%.

Dr Kitahori. That is room air.

Dr Tweddell. And normocapnia?

Dr Kitahori. Yes.

Dr Renato S. Assad *(Sao Paulo, Brazil).* I just would like to share with the Association some comments about this technique. We have used adjustable PA bands for high-risk patients with hypoplastic left heart syndrome, a simple method to percutaneously regulate the pulmonary blood flow over time. Regarding our protocol of adjusting the PA bands in the operating room, the precise degree of banding ring constriction is adjusted after sternal

closure. Because we do not have TEE for small neonates, we ask the anesthesiologist to keep the fraction of inspiratory oxygen in the 21% to 30% range to be able to achieve SaO_2 in the low 80s during banding adjustment. That is our straightforward protocol for PA banding adjustment, trying to administer the same amount of volume in both banding cuffs to achieve similar blood flow to both lungs. This system has allowed stable SaO_2 in the low 80s throughout the interstage 1-2.

Dr Kitahori. Thank you for your comments.

Dr Hideto Shimpo *(Tsu, Mie, Japan).* I congratulate Dr Kitahori on very interesting data. I have a couple of questions.

Are there any differences between the RPA groups and the LPA groups at the Fontan procedure?

Dr Kitahori. Sometimes we have seen LPA stenosis, but it has not been so severe. We did not need PA-plasty for LPA stenosis, but it can be a problem of this technique. The PA band can cause PA stenosis, especially at the PA banding site. However, we have not needed any PA-plasty so far and have just inserted a dilator into the LPA, which has been good enough.

Dr Shimpo. My second question: I think this technique is a very good option for complex disease, so have you applied this technique to other complex diseases, for example, truncus arteriosis and so on?

Dr Kitahori. I think bPAB is a good option for other diseases, but we have few such cases. So, I cannot comment on that, sorry.